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# Fluoridation of Public Water Supplies



REPORT OF FLUORIDATION COMMITTEE

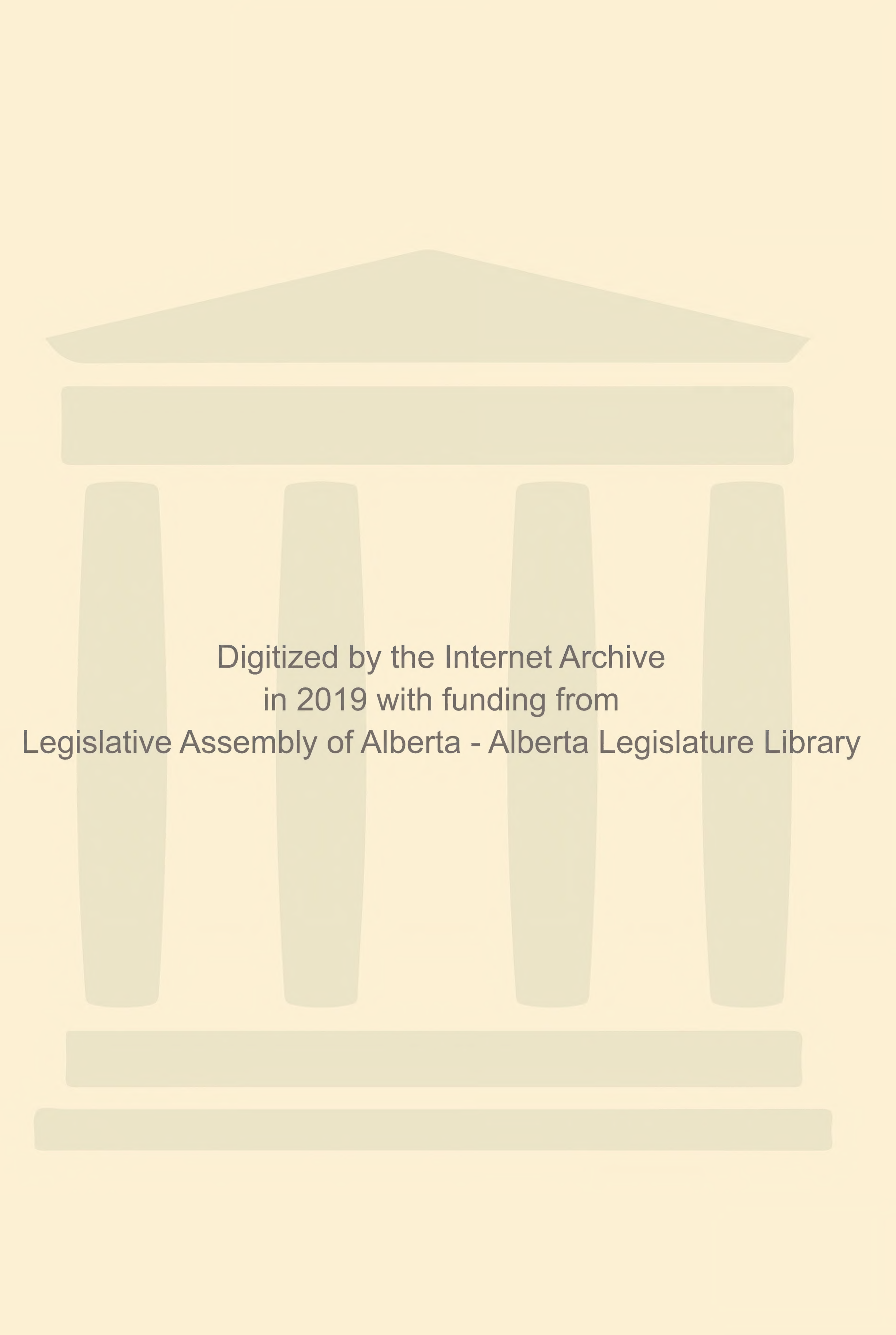
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EDMONTON

November 1st, 1954



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# Fluoridation of Public Water Supplies



## REPORT OF FLUORIDATION COMMITTEE

**RESEARCH COUNCIL OF ALBERTA  
UNIVERSITY OF ALBERTA**

EDMONTON

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Dr. M. M. CANTOR.....	Provincial Chief Coroner, Edmonton
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## INTRODUCTION

The Research Council of Alberta on January 27, 1953, appointed a committee to make an unbiased technical survey concerning the merits of fluoridating public water supplies to prevent tooth decay and to make recommendations to assist the Research Council in advising the Government regarding this problem.

The committee comprised a group of seven individuals representative of the professions of education, law, chemistry, dentistry, medicine, engineering, and general science. The breadth of interest, responsibility and experience represented on the committee contributed to a scientifically critical study of the subject, and sympathetic consideration was given to the many diverse points of view which were brought forward.

The committee thoroughly familiarized itself with the background literature on fluoridation, the following being typical of the extensive study involved. For example, reference was made to the National Research Council supplement to the Proceedings of the first meeting of the Executive of the Associate Committee on Dental Research entitled: "Water-Borne Fluorides and Dental Health," issued in 1946. That report contains 159 references to the literature. Similarly, the scientific background is also presented in "Dental Caries and Fluorine," published in 1946 by the American Association for the Advancement of Science which contains eleven articles (111 pages) and lists several hundred references. Many of the literature references were read by committee members in the original scientific journals concerned; for instance, the numerous papers of Dr. Leo Spira were circulated among committee members.

The reports of various committees and commissions have proved most helpful. As indicative of the nature of these, special reference is made to the Delaney Committee Report which is included in "Chemicals in Foods and Cosmetics—Hearing before the House Select Committee to investigate the use of chemicals in foods and cosmetics—82nd Congress, Second Session, Washington, D.C., 1952," and to "The Fluoridation of Domestic Water Supplies in North America as a Means of Controlling Dental Caries," a report of the United Kingdom Mission, 1952. A particularly critical and detailed study was accorded to the reports on "study areas," that is, where experimentally-controlled fluoridation is being applied. Among these may be mentioned Grand Rapids, Michigan; Newburgh,

New York; Brantford, Ontario; Sheboygan, Wisconsin; Marshall, Texas; and Evanston, Illinois. All reports of the Canadian study published by the Department of National Health and Welfare have been most carefully studied, including "Dental Effects of Water Fluoridation—1954," dealing with the Brantford-Stratford-Sarnia study. Furthermore, much is available in the form of pamphlets and newspaper and trade journal articles, and everything of this type that was drawn to the committee's attention was procured and studied. As an example, mention may be made of the articles included in "Fluoridation—Boon or Blunder," by Betty Lee, The Globe and Mail.

The committee feels that it has studied the great bulk of the literature on this subject. It has not only considered the scientific evidence dispassionately but has attempted to give the most careful and sympathetic consideration to all points of view brought forward, including the various alternate methods proposed for making fluorine available to the body.

After a lengthy period of study the committee **has presented its findings in four sections dealing with the chemical, medical, dental, and engineering aspects of the problem.** Of necessity, there is some overlapping because it is impossible to segregate the various sections completely. The recommendations of the committee are given in Section V and are based on the findings presented in Sections I to IV.

## SECTION I

### CHEMICAL ASPECTS

When natural waters come in contact with soils and rocks, some of the constituents of these are dissolved. Some of the dissolved material may be organic, but most of it will be present as inorganic salts. Later, the water emerges in wells, springs, rivers or lakes and carries with it substances in solution varying in character and quantity with the type of rock or soil through which it passed as well as on the time of contact. For example, if the water has passed through a limestone bed, calcium bicarbonate will be found in solution; if through a gypsum bed, calcium sulfate; if through a rock phosphate bed, calcium phosphate and calcium fluoride. Salts vary widely in solubility, and thus the concentration of any of them in the water supply will be limited by this factor as well as by the time of contact between the water and the strata.

Concentration of dissolved salts in water is generally expressed in terms of the corresponding ions as dissociation will be of the order of 100%. **The concentrations are expressed on the basis of the number of parts of the substance in one million parts of water and are written as p.p.m.**

**In the case of fluorides in natural waters, the concentration of fluoride ion varies from less than 0.1 p.p.m. up to 14 p.p.m.** In the Province of Alberta the variation for the waters examined is from less than **0.1 p.p.m. up to 4.5 p.p.m.** Table 1 shows the results from over 1,000 Alberta waters. In general, surface waters and shallow well waters are low in fluoride, while that from deep wells may or may not be high in fluorides depending to a large extent on the locality. These conclusions are arrived at by consulting this table.

**TABLE 1**  
**DISTRIBUTION OF FLUORINE WATERS IN ALBERTA**

	Number of samples examined	Number of water samples with fluorine content of		Samples containing 0.9 p.p.m. and over as per cent. of total number of samples examined
		0.9 p.p.m. and over	Less than 0.9 p.p.m.	
<b>(1) Western Alberta Area—Low Fluorine Region</b>				
Deep wells .....	18	2	16	11.1
Shallow wells.....	76	1	75	1.3
Surface water.....	19	2*	17	10.5
Unknown .....	56	2	54	3.5
Total.....	169	7	162	4.1
* Samples from sulphur spring at Banff				
<b>(2) Peace River Area—Medium Fluorine Region</b>				
Deep wells .....	7	2	5	28.6
Shallow wells.....	20	1	19	5.0
Unknown .....	19	3	16	15.8
Total.....	46	6	40	13.0
<b>(3) Edmonton-Wetaskiwin Area—Medium Fluorine Region</b>				
Deep wells .....	42	17	25	40.5
Shallow wells.....	41	2	39	4.9
Surface water.....	10	0	10	0
Unknown .....	24	4	20	16.7
Total.....	117	23	94	19.7

TABLE 1 (Continued)

	Number of samples examined	Number of water samples with fluorine content of		Samples containing 0.9 p.p.m. and over as per cent. of total number of samples examined
		0.9 p.p.m. and over	Less than 0.9 p.p.m.	
<b>(4) Red Deer-Calgary Area—High Fluorine Region</b>				
Deep wells .....	57	33	24	58.7
Shallow wells.....	43	8	35	18.6
Surface water.....	5	0	5	0
Unknown .....	35	9	26	25.7
Total.....	140	50	90	35.7
<b>(5) Lethbridge Area—High Fluorine Region</b>				
Deep wells .....	60	45	15	75.0
Shallow wells.....	36	10	26	27.8
Surface water.....	16	1	15	6.3
Unknown .....	29	11	18	34.6
Total.....	141	67	74	47.5
<b>(6) East Central Area—Low Fluorine Region</b>				
Deep wells .....	46	7	39	15.2
Shallow wells.....	129	3	126	2.3
Surface water.....	4	0	4	0
Unknown .....	71	4	67	5.6
Total.....	250	14	236	5.6
<b>(7) Coronation Area—Medium Fluorine Region</b>				
Deep wells .....	10	4	6	40.0
Shallow wells.....	17	1	16	5.9
Surface water.....	1	0	1	0
Unknown .....	12	0	12	0
Total.....	40	5	35	12.5
<b>(8) Southeastern Area—Low Fluorine Region</b>				
Deep wells .....	31	3	28	9.7
Shallow wells.....	37	4	33	10.8
Surface water.....	6	0	6	0
Unknown .....	38	2	36	5.3
Total.....	112	9	103	8.0
<b>S U M M A R Y</b>				
Deep wells .....	271	113	158	41.7
Shallow wells.....	399	30	369	7.5
Surface water.....	61	3	58	4.9
Unknown .....	284	35	249	12.3
Total.....	1015	181	834	17.9

The water supply is the chief source of fluoride in the diet. There is some fluorine in plants, the amount depending on the plant species to some extent but also on the amount of fluorides that can be dissolved by the soil solution. What is absorbed by the plant will be incorporated in the plant tissue, but all available evidence indicates that it is still in the inorganic form (**that is, the fluorine is present as fluorides**). The fluorine content of plants is generally low as can be seen in Table 2. This table contains some of the common vegetable foods and the fluorine contents shown are on the dry basis. It should be noted that tea is exceptionally high in fluorine.

**TABLE 2**  
**FLUORINE CONTENT OF VEGETABLE FOODS**

Food	Fluorine content, p.p.m. (dry basis)
Whole wheat flour.....	1.3
White flour .....	1.1
White bread .....	1.0
Honey.....	1.0
Cocoa.....	0.5 to 2.0
Tea.....	30. to 60.
Cabbage.....	0.3 to 0.5
Tomatoes.....	0.6 to 0.9
Potatoes.....	0.2
Apples .....	0.8
Oranges .....	0.2

When animals drink water and eat foods of vegetable and animal origin, most of the fluorine in these is excreted chiefly in the urine. Some fluorine enters the bones and the teeth where it replaces some of the hydroxyl and carbonate groups in the fluorapatite. This is especially true in young animals, as it takes place when the teeth are forming and the bones are developing. Thus the fluorine remains in the inorganic form. There is no accumulation of fluorine in specific organs or glands as is the case with other "trace" elements such as iodine, manganese, zinc or copper. These elements differ from fluorine in that they become part of organic compounds.

Some analyses of foods of animal origin are contained in Table 3. The values shown are on the basis "food as consumed." Of the foods listed in the table, canned fish are highest in fluorine content because they contain the bones.

**TABLE 3**  
**FLUORINE CONTENT OF ANIMAL FOODS**

Food	Fluorine content, p.p.m. (as consumed)
Milk.....	0.1 to 0.2
Butter.....	1.5
Cheese .....	1.6
Beef .....	0.2
Veal.....	0.2
Chicken.....	1.4
Pork.....	1.0
Oysters.....	1.5
Canned salmon .....	8.5 to 9.0
Fresh fish.....	1.6 to 7.0
Canned sardines.....	7.3 to 12.5

Calculations have been made of the contributions by water and foods to the fluorine content of the diet. Eating and drinking habits vary with the individual, with the extent of physical activity, and with temperature. According to McClure, Armstrong and others, normal mixed diet provides approximately 0.3 to 0.5 milligram fluorine per day. If water contains

1 p.p.m. fluorine and if consumption for drinking and cooking is 1.2 to 1.6 quarts per day, the water will contribute about 1.2 to 1.6 milligrams fluorine daily. Under these conditions, water is a more important source of fluorine than foods.

As illustrated by Table 1, there is a considerable variation in the fluorine content of water supplies and thus in the amount of fluoride ingested by people in different communities. When the fluorine content of the water is 1 p.p.m. or greater, some of the children may have teeth that are mottled. This condition—known as dental fluorosis—may be mild or severe depending on the fluorine content of the water at the time the teeth are forming. If the fluorine content is 1 to 2 p.p.m. there are dull white spots on the teeth, while with 2.5 to 5 p.p.m. the discolorations may be yellow, brown, or black as the fluoride concentration increases. This discoloring of the teeth detracts from their appearance.

Millions of people in the world use water with a fluorine content of 1 p.p.m. or greater. Their teeth are mottled to a greater or less degree. This applies to parts of rural Alberta where the extent of mottling agrees very well with the fluorine contents of the water as shown in Table 1.

Even before 1931—when it was shown that mottling of teeth is caused by fluorides—it had been observed that mottled teeth are structurally strong and less liable to be affected by dental caries than normal teeth. Many such observations were reported in the period between 1931 to 1945, including a number from the Province of Alberta. These data were tabulated and studied. Additional surveys were made in many communities where a comparison was made between the fluorine content of the water supplies and the incidence of dental caries. The mass of evidence established the relationship between dental caries and the fluorine content of the water supply. A low fluorine content in the water went hand-in-hand with high incidence of dental caries, and a high fluorine content with relatively low incidence of dental caries. There seemed to be no other factor that would account for this variation in dental caries.

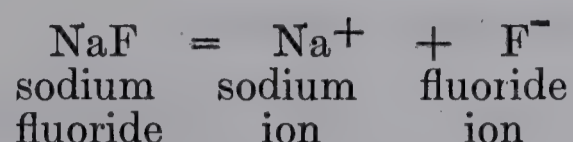
It was, therefore, proposed that fluoridation of water supplies low in fluoride be undertaken in selected communities. Examination of data from communities with naturally fluoridated water supplies indicated that the greatest benefit would be received if the fluorine content of the water were brought up to 1 p.p.m. where protection against caries would be great and the chance of mottling of teeth would be at a minimum.

About 1,000 public water supplies in the United States and Canada have now been fluoridated. The earliest of these treatments was commenced in 1945 in the following cities: Grand Rapids, Michigan; Newburgh, New York; Brantford, Ontario. In each of these cases parallel observations were carried out in neighboring cities with no fluorine in their water supplies. One of the essential features of these programs has been extensive yearly examination of the teeth of children in the cities involved.

The experimental evidence coming from these projects have all agreed that there has been a great reduction in dental caries in children of different age groups, the reduction ranging from 40 to 60 per cent.

Fluoridation is carried out by feeding, mechanically, a soluble fluoride into the water supply. The quantity used is the amount required to bring the fluorine content of the water up to 1 p.p.m. Sodium fluoride (NaF) is the compound used most extensively, but some communities are using

hydrofluoric acid ( $\text{H}_2\text{F}_2$ ) or sodium fluosilicate ( $\text{Na}_2\text{SiF}_6$ ). Sodium fluoride in dilute solution is completely ionized to give fluoride ions, as follows:



It behaves, therefore, exactly the same as the fluoride present in naturally fluoridated water. Sodium fluosilicate also ionizes extensively in dilute solutions to give fluoride ion, and thus behaves similarly to sodium fluoride occurring naturally in the water supply or added to it.

**It must be emphasized that the fluorides added when water is fluoridated are of like properties—both physical and chemical—as those that occur in naturally fluoridated water.**

## SECTION II

### MEDICAL ASPECTS

This section is concerned primarily with the effects of fluorine on health and disease. It is based on adequate and available scientific studies, and represents the mature opinion and judgment of recognized authorities on the subject. In this report "fluorine" refers to fluoride ions or the fluorine portion of a compound containing this element.

#### Occurrence of Fluorine in Food and Water

Fluorine is widely distributed in nature. Like many other elements, it is present in trace amounts in a wide variety of natural and prepared foods and in varying concentrations in natural water supplies. Articles of food derived from animal sources—particularly fish, milk proteins, and meat—contain relatively large amounts of fluorine in comparison to the amounts obtained from most vegetable sources. Prepared foods containing bone extractives and animal tissue concentrates have a particularly high fluorine content. It is estimated that the average diet provides from 0.19 to 0.32 milligram fluorine daily.

Public water supplies—particularly those of large communities—are derived from rivers, lakes, and ponds. Some of these sources are practically fluoride-free; others contain as much as 1.5 p.p.m. (parts per million) fluorine. Water supplies obtained from deep wells have concentrations of fluorine ranging up to 8 p.p.m., and occasionally even more. The amount of fluorine ingested daily as drinking water varies with the concentrations in the supply and with the water drinking habits of the individual. In temperate climates, the average daily consumption of drinking water by adults is about 1,200 to 1,600 cubic centimeters. Water which contains 1 p.p.m. fluorine would contribute 1.2 to 1.6 milligrams fluorine each day. Water containing 5 p.p.m. fluorine would provide 6 to 8 milligrams to the total ingested. In children up to the age of twelve, these values are reduced about 25%.

The amount of fluorine ingested daily as food is small, and because of its complex nature in foods this fluorine is not readily assimilated by the body. In contrast, fluorine ingested as water containing 1 p.p.m. represents the most effective source of the element in a form which is readily assimilated and available for the metabolic processes.

#### Toxicity of Ingested Fluoride

The poisonous nature of fluorine and its compounds is a matter of common knowledge, since it is used widely as a poison for pests. Fluorides rank prominently among the substances which, taken in small amounts, cause death within a relatively short time. The lethal dose in animals—that is, the dosage from which 50% of the animals die—is about 50 milligrams per kilogram of body weight. This is presumably the lethal dose in humans. The minimum amount known to have caused death in man is 4,000 milligrams taken as a single dose.

It has been demonstrated that sodium fluoride given in doses of 20 to 50 milligrams four times daily to children aged 3½ to 6 years, and in doses of 80 milligrams four times daily to adults, did not produce any evidence of toxicity. Comparison of these figures (80 to 320 milligrams sodium

fluoride per day) to those provided by water containing 1 p.p.m. fluorine (1.2 to 1.6 milligrams per day) emphasizes the wide margin of safety insofar as acute toxicity is concerned.

There are many instances of fluoride poisoning in humans, some accidental and more where the fluoride was taken with suicidal intent. The acute toxic effects of fluoride are well known, but have no bearing upon the possible hazards associated with the presence of fluoride to the extent of 1 p.p.m. in drinking water. Any hazards that may arise from drinking such water will be those which might result from the possible cumulative action of fluorides, that is, by the storage of fluorides in the body, though there is no evidence which would indicate this to be the case.

A form of chronic intoxication by fluoride (fluorosis) does exist in animals. In Morocco, "dormous" is a common affection of the teeth and jawbones of sheep and cattle pastured on soils contaminated by volcanic deposits high in fluorine content. This is seen also in Iceland as "gaddur," and has been noted in animals grazing in the vicinity of aluminum works in Switzerland and in the Columbia River Valley in Washington and Oregon States. In these latter instances, it is due to atmospheric contamination with hydrofluoric and hydrofluosilicic acids.

Different species—and different individuals in the same species—vary in their susceptibility to fluorides and show differences in the changes produced. Susceptibility is increased by malnutrition, so that the bones and teeth of healthy animals may contain the same amount of fluoride as those of malnourished animals with definite symptoms of fluorosis. Many experimental studies dealing with the incorporation of fluoride in the diet of animals have been completed and it has been shown, for example, that fluorosis develops more rapidly on diets low in calcium than on those rich in calcium, phosphorous and Vitamin D. Sufficient evidence has also been presented to indicate that the effect of fluoride is dependent upon the dose, the form of administration and the duration of intake, as well as on the composition of the diet.

These experimental studies all deal with fluorine-containing diets in which the fluorine is greatly in excess of 1 p.p.m. Thus, rats receiving 0.09% of their daily intake as fluorine (that is, 900 p.p.m.) die—in from a few days to a few months—after a period of inanition followed by lethargy and weakness. Rats feeding on a diet containing 300 to 900 p.p.m. showed lessened appetite and reduced growth. Those taking 100 to 300 p.p.m. fluorine in their food showed some inhibition of growth. Where the dosage was less than 100 p.p.m. no changes were noted in appetite, growth, reproduction, or development. Similar experiments with dogs and rabbits provided essentially similar findings.

## **Chronic High-Grade (Severe) Fluorosis in Humans:**

### **1. From Inhalation of Fluorine-Containing Dusts**

Many careful studies have been made in humans exposed to fluoride-containing dusts under industrial conditions. Studies in such instances have shown that abnormal bone density develops particularly in the vertebral column and in the pelvis and that there is thickening of the trabeculae in the lower jawbones. Occasionally, spicule formation has been noted in tendon attachments. In most cases studied, examination of the data presented reveals that there is no associated pain or discomfort and no effect on the productivity, disease incidence, or life expectancy of the workers. Among some notable exceptions described by a Danish in-

investigator of workers in the cryolite industry, one person developed stiffness of the joints, twenty-two had a loss of appetite, and some showed anemia. Others had respiratory disorders associated with the inhalations of the dusts. In none of the cases is there any evidence that disability preceded the development of bone changes detectable by radiographic means.

## **2. From Ingestion of Fluorine-Containing Water**

Nearly all of the cases reported in the literature come from China, South Africa, India, Italy, and the Argentine. These cases, the total of which does not exceed fifty, have been exposed to water containing natural fluorine from 2 p.p.m. to 16 p.p.m. for many years. All show mottled enamel associated with varying degrees of stiffness of the back and bony changes. In many of the cases reported, increased bone density was assumed to be present and was not confirmed by radiological means. All of these cases also suffered from severe malnutrition. One well-authenticated case is reported in the U.S. literature. This was a man who died at the age of thirty. He had lived for twelve years in an area where the water supply contained 12 p.p.m. fluorine; two years in an area where the water contained 5.7 p.p.m.; seven years at 4.4 p.p.m.; two years in a low fluorine area; and finally seven years at 4.4 p.p.m. This man developed a severe kidney disorder when he was fifteen years of age. He developed bone density changes but showed no spine stiffness, and the investigator speculated as to whether the fluorine aggravated the kidney condition or promoted the development of the bony changes.

The mechanism by which high-grade chronic fluorosis develops is not completely known, but all the changes observed are associated with derangements in mineral metabolism. It has been suggested that fluoride, being an enzyme-inhibiting agent, might interfere with the phosphatase activity essential for normal calcification of bone. This is unlikely since it has been demonstrated that depression of phosphatase activity requires a concentration equivalent to 100 p.p.m. fluorine.

## **Chronic Low-Grade (Mild) Fluorosis in Humans**

This term has been applied to persons showing "mottled enamel" changes in the teeth, and the condition is associated with the ingestion of fluorine-containing water over a long period of time. This phase of the subject is dealt with separately under "Dental Aspects," and requires no repetition here. It is pertinent, however, to emphasize that the hardly perceptible white spots are the earliest and most delicate sign of chronic fluorosis; that it is relatively easy to recognize and is thus the best clinical criterion to use as a safeguard against overdosage. Examination of all the available scientific evidence fails to reveal any other effect which can be attributed to water containing 1 p.p.m. fluorine.

## **Metabolic Fate and Storage of Fluorine**

It has already been noted that an adult living in temperate climates and drinking water containing 1 p.p.m. fluorine ingests 1.2 to 1.6 milligrams fluorine per day (children to age twelve—0.8 to 1.1 milligrams per day). While the exact kidney threshold for the excretion of fluoride has not been established, it has been shown that when the total amount ingested is 4 to 5 milligrams per day excretion by the kidneys and sweat prevents storage of any significant amount. It has also been demonstrated experimentally in humans that the efficiency of excretion is improved if fluorine is ingested in normal amounts over a long period of time.

Data on urinary excretion of persons ingesting water containing large amounts of naturally occurring fluorine offer the most satisfactory evidence along this line. In 1900 cases studied carefully, it has been shown that where the water consumed contained from 0.2 p.p.m. to 4.7 p.p.m. fluorine the urinary fluorine approximated that ingested, so that none—or very little—was stored in the bones.

Fluoride ingested in excessive amounts is stored in bones. Normal human bones contain about 0.09% fluoride. Two cases of fluorosis with coincident severe kidney disease and impaired excretion showed a bone content of 0.65% and 0.72%.

## **Fluorine and Disease**

### **1. Effect on bone**

It has been noted that radiological changes can occur in the spinal and other bones of workers exposed to dusts containing high concentrations of fluoride, but disability is not common even among men who have been exposed for years. There is no clear-cut evidence relating the existence of bony abnormalities among populations using water supplies containing fluorides at the level recommended for caries control. There is no relationship between fracture incidence and exposure to fluoride, and bone growth is not impaired. It has been suggested that among malnourished populations exposure to fluorides at a level of 6 p.p.m. may produce spinal deformity. This finding has not been confirmed, and it is more likely that malnutrition in itself is the probable cause.

### **2. Effect on Growth**

Height and weight records of men exposed to the highest water fluorine concentration under natural conditions show no appreciable difference from those coming from areas of low water fluorine concentration or from those with no fluorine at all. Similar investigations showed that the height and body weight of over 1,400 boys studied compared favourably with the height and weight data set as accepted standards throughout the North American continent. The height and weight data are in no way related to fluoride exposures.

### **3. Effect on Thyroid Disease**

Information obtained by careful investigation shows no evidence that fluorine in any way plays a part in human hyperthyroidism by its action on the thyroid gland. While it is conceivable that if a large amount of fluorine were stored in the thyroid it might interfere with iodine metabolism, sound scientific grounds for such an assumption have not been presented.

### **4. Effect on the Special Senses**

There is no evidence to support the suggestion that fluoride in concentrations found in water supplies—or in water containing 1 p.p.m. fluorine—affects visual acuity.

There is statistical evidence that hearing defects are more common in children coming from low fluoride districts than in those from districts with fluorine content not over 1.4 p.p.m. This cannot be taken to mean that fluorine improves auditory acuity.

## 5. Effect on Cancer

It has been suggested that water containing 0.44 p.p.m. fluorine favoured the early development of cancer in mice of a special cancer strain. There was no increase in incidence. This work, on examination, showed several scientific flaws. It was found, for example, that the experimenter was unintentionally providing 42 p.p.m. fluorine in the diet fed to the mice, and further, that 96 to 100% of this particular strain of mice succumbs to cancer, regardless of the diet or of the water supply. So far as human cancer is concerned, there is no evidence whatever that the presence of fluoride in public water supplies has any harmful effect. In fact, statistical studies indicate that cancer rates are lower in States of the U.S.A. where there are many fluoride endemic areas than in States where the waters are fluoride-free. There is, however, no reason to believe that these lower cancer rates are due to the presence of fluorides in drinking water.

## 6. Effect on Nephritis

The suggestion has been made that the continued consumption of fluoridated water may impair kidney function—especially in persons suffering from kidney disease—and that the accumulative storage in those cases in bone and other tissues will ultimately reach a dangerous level. Intensive studies of the statistics available have failed to reveal any atypical clinical effects among cases of nephritis in areas where the water contains natural fluorides in concentrations far greater than 1 p.p.m. fluorine.

From what has already been said about the excretion of fluoride, it is clear that the ability of the body to handle fluoride is more than adequate for the amount ingested through fluoridated water containing 1 p.p.m. fluorine.

## Epidemiologic Evidence of Harmlessness

Several million people all over the world live in areas where fluorides occur naturally in the water supplies in concentrations of 1 p.p.m. fluorine or more. There is no evidence that such naturally fluoridated water differs in any way—which is of biological significance—from water to which fluoride has been added. Furthermore, chemical evidence indicates strongly that in both kinds of water—naturally and artificially fluoridated—the fluoride at the concentration concerned is completely ionized. In other words, it is the fluoride ion which is important and not the fluoride salt from which it is derived. If this is accepted, then the evidence of benefit or harm can be derived not only from the experience following the addition of fluorides to water but also from the health experience of the vast number of people who have always consumed water with a naturally high fluoride content.

It has been well known for more than twenty-five years that workers exposed to industrial dusts and smokes heavily loaded with fluorides, are liable to bone deformities; and that children consuming water with a high fluorine content several times in excess of that needed to control dental caries, may develop mottled teeth to a degree considered unsightly. Research into the toxicology of fluorine compounds has been continuous, and the possibility that low level consumption might eventually cause undesirable effects has been recognized for many years. Yet over all these years there has been no definite evidence that the continuous consumption of fluorides at a level of 1 p.p.m. fluorine is in any way harmful to health. This is a most impressive fact, and one which makes it entirely certain that if any untoward effect is ever revealed by future research it will be

of a very trivial order. If such a possibility has to be considered as a calculated risk—or if a risk exists at all—it is so inconspicuous that it has not been revealed by many years of investigation. So many millions of people are now living and enjoying good health on water containing fluoride in the amount recommended for caries control—or more—that it becomes apparent that fluoridation of other waters involves no new experience in human welfare.

### **Safeguards Against Chronic Fluorosis**

Consideration of the available evidence indicates that the risk to public health from fluoridation of the water is negligible. It is, nevertheless, desirable to consider the means by which manifestations of chronic low-grade fluorosis could be detected in the population before it had progressed to what might be considered to be physiologically undesirable. Dental examination could certainly reveal occurrence of mottling, a phenomenon which becomes apparent long before any skeletal effects could be expected to show. Determination of urinary fluoride at intervals of a few years might serve as an additional safeguard. Such a procedure is no different than that of periodic vaccination—or of reinforcing inoculation for diphtheria—and certainly less complicated.

The possibility of the ingestion of fluoride from sources other than water must be considered. Industries producing disabling fluorosis do not exist in Alberta. Industries which might become possessed of such hazards could be controlled by bringing their fluoride exposure within the currently accepted safe limits.

Fruits and vegetables may become contaminated by residual fluoride dusts, following the use of fluoride-containing insecticides in orchards and fields. The proper control of this lies with the Pure Food and Drug Administration which could set limits compatible with the presence of 1 p.p.m. fluorine in the drinking water without affecting the suitability of the spraying agent.

### **General Observations Concerning Fluoridation of Water**

In cities where fluoridation of water has been introduced there have been no complaints of significance from industrial users of the water and no harm to lawns and plants has been seen. The taste of the water is unaffected. Fluoride contributes nothing to the value of the water used for purposes other than drinking. Fluoridation does not represent involuntary mass medication as fluoride does not exert any therapeutic action. It does not bring about a repair of the damage wrought by dental caries. In a sense it is mass prophylaxis, although this term is unsuitable because no foreign substance is added to the water. **Actually, all that is proposed is that the concentration of a substance naturally present in the water supply shall be increased to a level which has been demonstrated to be optimal for dental health. Such a procedure is neither more nor less than the addition of Vitamin A to butter or to margarine, or the addition of Vitamin B Complex members to flour.**

### **Summary and Conclusions**

Fluorine is a trace element essential in human nutrition. The most important and effective source of fluorine in the diet is in the drinking water. Many of the public water supplies are deficient in fluorine, and children

dependent upon such supplies have a high dental caries attack rate as compared to children living in cities having water supplies containing about 1 p.p.m. fluorine. Sufficient evidence has been presented to indicate that there is a safe margin between drinking water containing the trace quantities of fluorine which are required for optimal dental health and that amount which produces undesirable physiological effects. There is no reason to believe that prolonged ingestion of drinking water with a mean concentration below the level causing mottled enamel will have an added physiological effect.

Like any other new measure which affects a large number of people, fluoridation has met with opposition from minority groups. Fluoridation, like any other preventative program, must be in operation for several years before nation-wide acceptance can be expected. At the same time, the idea of fluoridation has a background of as much—or more—scientific data based on human experience than any other public health program at the time of its adoption, for example, vaccination, diphtheria inoculation, and the polio vaccine program. **Although studies are still in progress to determine the greatest amount of protection to be realized from fluoridation, there is ample evidence now to justify its use in any community where the water supply is deficient in fluorides, where the standards established by health authorities can be met, and where the process is carried out under adequate technical supervision.**

## SECTION III

### DENTAL ASPECTS

Dental caries or dental decay affects about 98% of the population in areas where no fluoride occurs in the water supply. A survey in Edmonton in 1935 of school children in grades 2 to 5 showed 97% had dental caries. There is no reason to believe the incidence would be different in 1954 if a similar survey were made. Uncontrolled or untreated dental caries lead to pain, infection (both local and systemic), and loss of teeth. Teeth lost in early childhood affect the growth pattern of the jaws and face. Oral infections from abscessed teeth contribute to general ill-health and disability.

#### **Endemic Dental Fluorosis (Mottled Teeth)**

The finding that there is a relation between fluorine and dental health had its beginning in the discovery, in 1931, that high fluoride concentrations in water cause a condition known as endemic dental fluorosis (mottled teeth). This condition is due to a disturbance in the calcification of enamel and dentine, and in its mildest form produces a chalky white enamel surface. As fluoride concentration increases, discrete or confluent pitting of the enamel surface with a characteristic brown staining may occur. The severity of dental fluorosis is proportional to the concentration of fluoride in the drinking water that is consumed during that period in childhood when teeth are being formed. Endemic dental fluorosis in a readily observable form appears only when the fluorine content of the water exceeds 2.0 p.p.m. (parts per million).

It was observed among children using fluoride-bearing water that the incidence of dental caries was very low, whether or not their teeth showed signs of fluorosis. This observation led to extensive epidemiological studies dealing with the relationship between fluoride and dental caries.

#### **Relation of Fluorides to Dental Caries:**

##### **1. In Areas Where Fluoride Occurs Naturally in the Water**

The low incidence of dental caries found among children living in communities whose natural water supplies contain fluoride has been clearly demonstrated by the epidemiological studies of Dean and his co-workers.

The optimal concentration of fluorine in the water appears to be about 0.8 to 1 p.p.m. Beyond this level there is little improvement in caries protection, and above 2 p.p.m. most of the children begin to show observable fluorosis.

It has been demonstrated repeatedly that children who have consumed fluoride-free water all their life, experience almost twice as much dental decay as do children whose natural water supply contains traces of this element. This protection against dental caries, due to the ingestion by children of the required trace of fluorides, apparently extends into adult life.

Since the shedding of deciduous teeth and the development and eruption of the permanent teeth is a continuous process extending up to about the twentieth year of life and because some topical effects from the passage of fluoride-bearing water over the teeth are likely, the benefits of water

fluoridation are not confined to the native-born population. The maximum protection is, of course, obtained by individuals of continuous residence.

## **2. In Areas Where Fluoride is Added to Fluoride-Deficient Water**

As early as 1945 certain communities—Brantford, Ontario; Newburgh, New York; and Grand Rapids, Michigan—adjusted the fluoride content of their water supplies by using fluoride salts fed by an automatic mechanical apparatus. These devices simulate and improve upon the process by which natural water supplies pick up their fluoride salts from the subterranean deposits of natural fluoride-bearing minerals. The effect of this controlled fluoridation has been to reduce the dental caries attack rate in the previously fluoride-deficient municipalities to the level observed in natural fluoride-bearing regions.

Phair and Driscoll's survey ("Status of Fluoridation Programs in U.S.," *Journal American Dental Association*, Vol. 45, Pages 555-582, Nov., 1952) showed that in the United States nearly 8,000,000 people in 367 communities were receiving fluoridated waters and that 317 additional communities serving 16,000,000 people had approved a program of fluoridation. Thus the adoption of a water fluoridation program is not without precedent.

## **Mechanism By Which Fluorides Reduce Dental Caries**

There are two possible mechanisms by which fluoride may protect teeth against dental caries:

(1) Bacteria are known to be involved in dental caries. Fluoride in certain concentrations inhibits many bacterial enzymatic reactions. Liberation of fluoride ion from the tooth substance may inhibit bacteria from participating in the dental caries process.

(2) Incorporation of fluoride into the tooth substance makes the tooth more resistant to acid etching.

It is possible that either of these mechanisms, or a combination of them, form the basis by which fluoride prevents dental caries.

## **Summary and Conclusions**

In a report of this nature it is impossible to describe in detail the many investigations which demonstrate the effectiveness and safety of fluoridation. It should be pointed out that in the well-conducted programs of fluoridation now in operation the benefits have been clearly demonstrated, both clinically and statistically, and that there have been no harmful effects. A 65% reduction of caries in children up to ten years of age has resulted. The results of fluoridating fluoride-deficient water supplies are paralleling those where the water naturally contains the proper amount of fluoride.

The evidence as a whole is consistent in offering assurance that increasing the fluoride concentration in public water supplies to the level known to be optimal for dental health is a prophylactic public health procedure which has an ample margin of safety.

In the United States, in 1945, the over-all costs of dental care amounted to 652 million dollars, and it is estimated that the 1953 costs will be well over the billion mark. In the 1952 Canadian National Sickness Survey, dental care in Canada was shown to cost 33 million dollars, which places dental services third from the top among expenditures made directly for

health services. But the backlog of oral ill-health is so great that this cost covers only that part with which the dental profession is able to cope—less than one-quarter of the total. From an economic, as well as a health viewpoint, there is a great loss by allowing endless investigations to delay the application of fluoridation as a preventative health measure. **It is estimated that for every dollar spent on fluoridation, sixty to seventy dollars will be saved in dental treatment.**

## SECTION IV

### ENGINEERING ASPECTS

The dental and non-dental physiological effects of fluoridated water supplies are discussed in other sections of this report. In this section the sanitary engineering aspects of the fluoridation problem are discussed under the following headings:

- Effect on industries;
- Chemical compounds used for fluoridation;
- Handling of chemicals;
- Application of fluoride to water supplies;
- Public health control;
- Summary.

#### Effect on Industries

There does not appear to be any serious adverse effects on industry of using water with fluorides at a level of 1.0 p.p.m. (part per million) fluorine. At Charlotte, N.C., where the water supply is soft, it was found that an increase in the fluorine content of the water from 0.1 p.p.m. to 1.5 p.p.m. caused 30 to 75% of the ice blocks to crack. This trouble was cured by the addition of 20 p.p.m. of ammonium chloride to the water used for the manufacture of the ice. It should be noted, however, that such difficulties have not been experienced at other places where similar fluoridated waters are used. Where silica is troublesome in boiler feed water, the addition of fluoride as sodium silicofluoride will add about 0.5 p.p.m. silica per 1.0 p.p.m. fluorine. Fluorine limits have been set for other industrial processes and are summarized below:

Use	Recommended threshold value, p.p.m.
Brewing.....	1.0
Carbonated beverages.....	0.2 to 1.0
Food canning and freezing.....	1.0
Food equipment washing.....	1.0
Food processing, general.....	1.0
Ice manufacturing.....	1.0

The recommended threshold values shown in the foregoing table were summarized from a number of references (see "Water Quality Criteria," State Water Pollution Control Board, Sacramento, California, 1952). Less than 1.0 p.p.m. fluorine has been recommended by some authorities as a maximum concentration for fluoride in water used for the manufacture of carbonated beverages. However, others have stated that 1.0 p.p.m. is satisfactory.

#### Chemical Compounds Used For Fluoridation

The desired effect of fluoridation is due to the fluoride ion. Therefore, in theory, any fluorine compound which will ionize in aqueous solution should have the same action on the teeth. To date only four compounds have been used, namely, sodium fluoride, sodium silicofluoride, hydrofluosilicic acid, and in one isolated instance, hydrofluoric acid.

The hydrofluoric acid is not liable to be used again, as it is dangerous to handle and presents special problems in feeding equipment which do not arise with any of the other compounds available.

Commercial hydrofluosilicic acid is a liquid containing about 30% of the acid, and is added to water in this form. It is corrosive to metals and necessitates the use of rubber or plastic materials for its conveyance. The acid is non-corrosive to skin or clothing, and accidental contact or spillage has not caused any injury or discomfort.

Both sodium fluoride and sodium silicofluoride are in general use in America. The solubility of the sodium fluoride is relatively constant over a wide range of temperature at about 4% by weight. The saturated solution has a pH of about 6.5 and is not seriously corrosive. The sodium silicofluoride is much less soluble, the solubility ranging from 0.43% at 32°F. to 0.62% at 60°F. and the saturated solution has a pH of about 3.5. Such a solution is corrosive, and plastics, rubber, and nickel alloy materials are recommended in connection with its use.

Sodium fluoride is more generally preferred for small installations up to about half a million gallons per day. For larger systems, the amount of chemical required makes it more economical to use sodium silicofluoride which is much the cheaper of the two; one other advantage is that it does not give rise to as severe incrustation problems in feed lines as does sodium fluoride, since calcium silicofluoride is more soluble than calcium fluoride. Calcium salts naturally occurring in the water give rise to this incrustation and, if present in large enough quantities, may have to be removed or modified by appropriate chemical treatment. The solubility of calcium fluoride seems to be such that, in water containing 1.0 p.p.m. fluorine, hardness as high as 300 p.p.m. as calcium carbonate has been reported as having no effect on the action of fluoride in the control of dental caries.

## Handling of Chemicals

The handling of the chemicals used in the fluoridation of water supplies is not hazardous provided that simple precautions are taken. Precautions in handling include suitable storage facilities, use of dust extractors, respirators and rubber gloves. In addition, the **urine** of operators may be tested periodically to ensure that a safe level of fluoride intake is not exceeded.

## Application of Fluoride to Water Supplies

The mechanics of feeding fluorides to water are no more involved than those for other chemicals used in water purification. Equipment already developed for adding other chemicals to water is readily adaptable for feeding fluorides.

Common methods of adding the fluorides to water include:

- (1) Solution feed of sodium fluoride;
- (2) Liquid feed of hydrofluosilicic acid; and
- (3) Dry feed of sodium fluoride or sodium silicofluoride.

Liquid feeders are used in small water systems to deliver solutions of sodium fluoride or hydrofluosilicic acid. For larger systems, dry feeders of either the volumetric or gravimetric type are used to deliver definite amounts of either sodium fluoride or sodium silicofluoride to the water supplies.

Experience has shown that the application of fluorides to water does not require an increase in the operating staff of the system. The cost, therefore, is essentially that of the equipment plus the chemicals used.

For most communities in Alberta this cost will range between ten and twenty cents per capita per year, depending on local conditions.

## Public Health Control

Because of the dangers involved in overdosages of fluorides to water, and because of the requirement of maintaining the minimum concentration to assure the benefits, it is necessary that supervisory control be exercised by the Provincial Board of Health over the fluoridation of public water supplies.

It is not within the scope of this report to recommend the exact text of regulations to govern fluoridation, but the following are a few principles on which sound control is dependent:

1. Regulations should provide that application be made to the Provincial Board of Health and approval given before any community commences to fluoridate its water supply. This provision gives reasonable assurance that no action will be taken without the knowledge of the controlling authority.
2. The Provincial Board of Health should have the power to order fluoridation stopped in any community in case proper precautions in its application are not being taken.
3. Daily analyses of fluoride concentrations should be conducted by the operators of the water systems and periodic samples sent to the Provincial Laboratory for analysis. All results should be reported to the Provincial Board of Health.
4. It is essential that the administration of such a control program be carried out by well-qualified sanitary engineers. This is especially important when fluoridation is being commenced. A sanitary engineer from the Provincial Board of Health should be present when fluoridation is being started in any community, and he should remain long enough to assure that the equipment is operating satisfactorily and that the operator is thoroughly conversant with the regulations, the tests to be conducted, and the operation of all equipment involved. Some consideration should be given to short courses of instruction, and possibly certification of operators, before allowing fluoridation of water supplies under their jurisdiction.

The existing regulations of the Provincial Board of Health governing the fluoridation of water supplies are considered to meet the foregoing principles adequately by providing the necessary safeguards and controls.

It is suggested that the rate of initiation of fluoridation be only as fast as the qualified engineering staff of the Provincial Board of Health can adequately supervise.

## Summary:

To date, there has been no indication that the presence of 1.0 p.p.m. fluorine in water supplies has any adverse effects on industries.

The sanitary engineering problems involved in the addition of, and control of, fluoride in water are readily solvable provided the necessary precautions are taken. **The most important of these precautions involves the acceptance of responsibility by the Provincial Board of Health to ensure that adequate supervision is given to the installation and operation of all fluoridation plants in the Province and that the operators in charge of such plants are sufficiently trained to be thoroughly conversant with the chemical tests and safety precautions involved in the fluoridation of water.**

## SECTION V

### CONCLUSIONS AND RECOMMENDATIONS

The evidence presented in the foregoing has led the committee unanimously to recommend the following:

WHEREAS the problem of dental caries is of a serious nature to peoples throughout the world; and

WHEREAS it has been shown by numerous population surveys and by many controlled fluoridation studies both in Canada and the United States that there is a significant reduction in caries incidence in those communities which use waters which contain dissolved fluorides, and that the results of fluoridating water supplies deficient in fluorides are paralleling those where the water naturally contains the proper amount of fluorides for the control of dental caries; and

WHEREAS no undesirable physiological effects have been observed either in children or in adults living in communities where the water contains no more than 1 part per million fluorine; and

WHEREAS the cost of adding soluble fluorides to water is relatively inexpensive, ranging from ten to twenty cents per capita per year for most communities; and

WHEREAS it is estimated that one dollar spent on fluoridation will save from sixty to seventy dollars in dental treatment; and

WHEREAS the supplementing of deficient water by the addition of fluoride presents no serious public health engineering problem; and

WHEREAS responsible health organizations, university departments of preventive medicine, and medical and dental associations in Canada, the United States and Great Britain have given their unqualified support to the fluoridation of water supplies; and

WHEREAS numerous large cities in the United States are adding fluorides to their water supply; and

WHEREAS various controlled studies in Canada and the United States have advanced to such a stage that they demonstrate the value and safety of adding fluorides to water;

**NOW THEREFORE BE IT RESOLVED THAT this committee gives its unqualified endorsement of the principle of the addition of soluble fluorides to fluoride-deficient public water supplies in Alberta to bring the fluoride concentration up to 1 part per million fluorine, subject to the detailed regulations of the Provincial Board of Health governing the fluoridation of water supplies.**









